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Report 68-2

**HIGH STABILITY IN REVERBERATION
UNDER SEA ICE (U)**

by

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and
T. Hughes

June 1968



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04 HIGH STABILITY IN REVERBERATION

UNDER SEA ICE (U)

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ABSTRACT

The acoustic environment beneath shore-fast arctic ice is extremely stable. Surface reverberation waveforms were identical in both amplitude and phase over periods of several minutes. Subtraction of two reverberation returns separated by one minute resulted in virtual elimination of the reverberation signal. Direct transmissions of signals through the water over a two mile path were stable except for small phase changes over a period of many hours. The phase changes were apparently connected with the doppler effect from tidal currents.



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In underwater echo-ranging, target echoes are often masked by the noise of reverberation. The maximum range of detection will therefore depend on a system's ability to differentiate between a target echo and the reverberation, each having known signal characteristics. Reverberation noise observed under shore-fast sea-ice is not the same as reverberation in ice-free seas ruffled by wind driven waves. The significant difference is that the geometry of the scatterers producing the reverberation can be fixed in ice covered seas but is random in ice-free seas. Under shore-fast ice, the geometrical stability permits successive reverberation waveforms to be identical, not simply in their respective envelopes, but cycle by cycle. This was shown by measurements made under the ice of M'Clure Strait in April 1968. It is these measurements that are the subject of this report. There exists the possibility of large gains in detection sensitivities with simple data processing techniques when the surface reverberation can be treated as a constant, deterministic signal, rather than a stochastic or random signal.

The two main points to be made in this paper are illustrated by Figure 1. Figure 1 shows the first ten seconds of reverberation received by a transducer mounted on the bottom in 400 meters of water covered by shore-fast ice. Note:

The short term acoustic environment is very stable. Figure 1 shows selected segments of the reverberation return expanded to show the individual cycles of the reverberation. Each expanded trace is composed by superimposing FIVE reverberation returns covering 64 seconds. The oscilloscope was triggered a fixed time after each transmitted pulse and the pictures show that the reverberation return was constant in both amplitude and phase. The variations, which are more noticeable with increasing range, were consistent with the noise level and there was no apparent instability in the reverberation.

The surface reverberation levels were very high. (Ref 1) A hint of the size of the underwater reverberators is given in Figure 2, which is a photograph of the ice surface near our camp.

The Experiment

Figure 3 shows the location of the camp on M'Clure Strait at approximately $74^{\circ}40'N$, $115^{\circ}E$. The camp, shown in Figure 4,

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was established on a frozen lead of smooth ice four feet thick. The lead ice was surrounded by jumbled and pressure-ridged ice, similar to that shown in Figure 2.

The transducer, shown in Figure 5, was omnidirectional in the horizontal plane, and was used for both transmitting and receiving at its resonant frequency of 900 Hz. The transducer on its stand was placed on the bottom in 400 meters of water.

A block diagram of the instrumentation is shown in Figure 6. The basic frequency source was a General Radio frequency synthesizer. The pulse generation and power amplification were digital, with micrologic counters controlling both the mark and the space. The power amplifier drove the line to the transducer with square waves, but the transducer matching network tuned out the harmonics so that the current in the line was sinusoidal. The acoustical signal in the water was essentially a coherent tone burst with each transmitted "ping" identical. A transmit-receive switch was not necessary since the amplifier was designed to inhibit the generation of self-noise during its quiescent period. A commercial preset counter, which counted the carrier frequency, was used to trigger the oscilloscope at a precise time after the transmitted pulse.

The outstanding result is clearly shown in Figure 1. Repeated reverberation waveforms were identical over time intervals of several minutes. Such minor variations as existed were masked by the noise level.

Over longer time intervals, the reverberation waveforms showed slow changes. Figure 7 shows the superposition of a few cycles of five reverberation waveforms sampled over a time interval of forty minutes. Each waveform is shown at a time 5.7 seconds after the time of transmission of a pulse. The variations are above the noise and show a slow trend in both amplitude and phase. The waveform changes were interpreted to be a result of slow variations in the environment. Since the transducer was omnidirectional, the reverberation signal represents the sum of reflections from many reverberators.

To study the variations of the environment, direct transmission measurements were made to a remote hydrophone, which was fixed just below the surface of the ice at a distance of two miles from the camp. The successive transmitted pulses received at this hydrophone showed a slow change in phase. Figure 8 shows

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these phase changes over a period of thirteen hours. The trend in the phase was shown by photographing one signal from the remote hydrophone each hour and displacing the traces vertically on the oscilloscope to preserve their time sequence. Over this time period a certain amount of faith is required regarding the stability of the transmitted signal, since we could not monitor its stability to this accuracy. It does seem significant, however, that the phase instabilities were regular and had a period of twelve hours. A changing tidal current with a maximum velocity of the order of a tenth of a knot would produce sufficient doppler effect to give the observed results.

Signal Processing

Figure 9 shows the results achieved with elementary signal processing. A simple subtraction of one reverberation waveform from another virtually eliminates the reverberation signal and leaves only the noise level. The noise level shown in Figure 9 was recorded with the power amplifier switched off, and represents the noise in one channel. If the noise in waveform A is assumed to be independent of the noise in waveform B then the noise component of A-B should be 3 db above the noise in one channel. The slight dependence of the A-B trace on reverberation envelope is probably caused by phase jitter in the analogue recorder. The 900 Hz reverberation signals were recorded in the field on analogue FM magnetic tape. At the laboratory the reverberations were digitized using a 3600 Hz clock signal also recorded on tape in the field. A digital computer performed a straightforward sample by sample subtraction of one reverberation signal from another and plotted the output shown in Figure 9. Figure 10 is similar to Figure 9 but represents a time five seconds after the ping rather than three seconds. The vertical gain in Figure 10 is 12 db greater than in Figure 9. The reverberations used for Figure 9 and 10 were chosen arbitrarily with no attempt at special selection.

Figures 9 and 10 show a subtraction of reverberations separated in time by one minute. When the time interval between pulses becomes greater the reduction caused by subtracting reverberation waveforms is less dramatic. For pulse separations of one hour the reduction in reverberation level through subtraction is in the order of 5 to 10 db. This may not be important. A detection system would only require that the stability extend over the time required for the target to make a movement significant in terms of the transmitted wavelength.

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It would be quite possible to design a Moving Target Indicator type of operational system based on the subtraction technique. This would allow an active, barrier type of detection system to operate in an environment effectively free of reverberation. Such a system would be insensitive in special cases, such as target movement of exactly one wavelength between the pulses that are being subtracted, but it should be easy to arrange the pulse timing so that only the most contrived of special cases would avoid detection.

Another possibility would be to make use of the direct transmission stability shown in Figure 8. It is hoped to investigate the sensitivity of the phase in a direct transmission path to forward scatter from a target. This could form the basis of a barrier type of system.

The whole concept of a high stability acoustic environment is startling, and it will take time to devise the best way of exploiting the phenomenon.

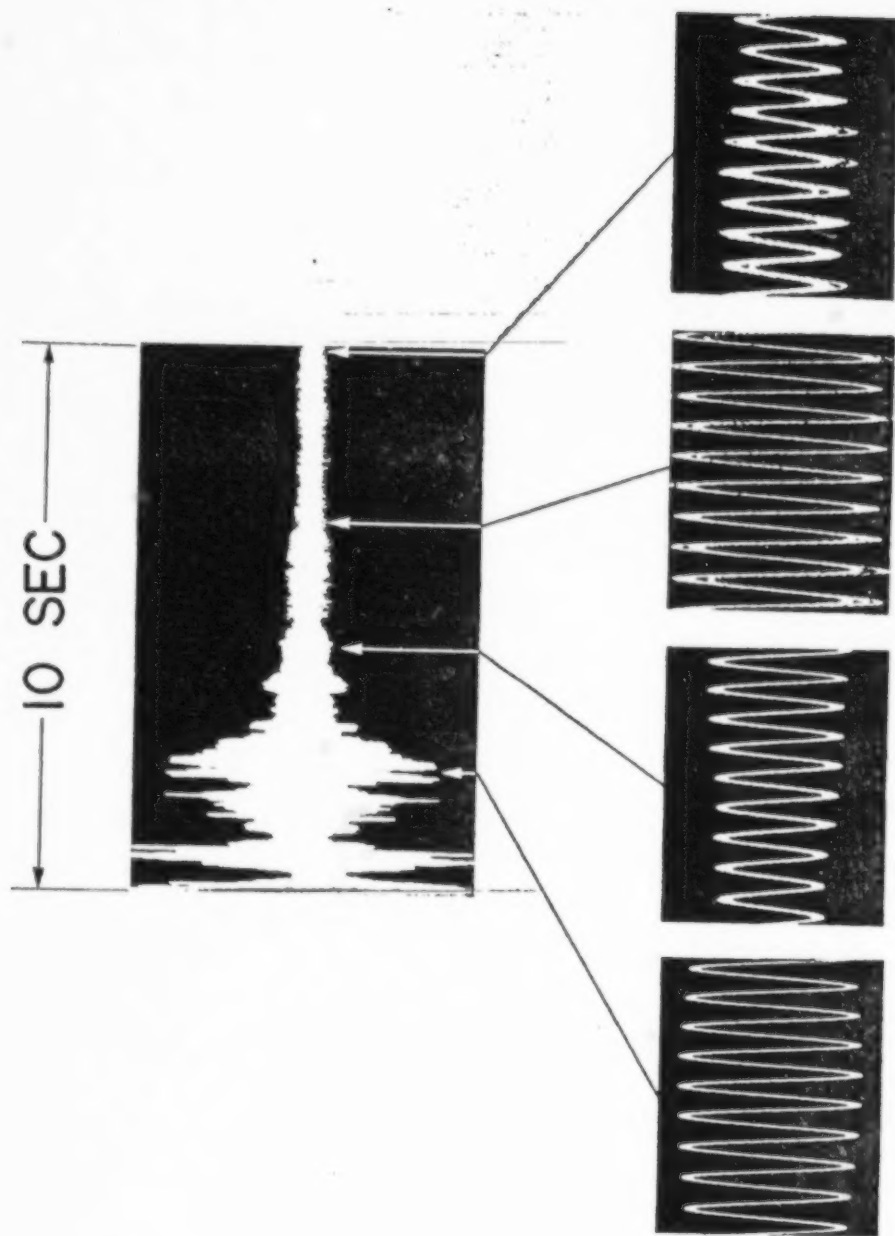
Summary

The stability of the acoustic environment under shore-fast arctic ice is very high - orders of magnitude greater than that of the open ocean. Surface reverberation from a fixed transducer is constant both in amplitude and phase for times of several minutes, and a simple subtraction of one reverberation return from another virtually eliminates the reverberation. The environment changes slightly over a period of hours, but this is likely due to tidal effects.

The reverberation levels were high, which confirms earlier measurements (Ref 1), and reverberation in the Arctic is more of a problem than in the open ocean unless advantage is taken of the very high stability revealed by this experiment.

Reference

J. R. Brown and A. R. Milne, Reverberation Under Arctic Sea-Ice. J. Acoust. Soc. Am., Vol 42, pp 78-82, July 1967.



EXPANDED PORTIONS OF 900 HZ REVERBERATION
SUPERPOSITION OF 5 TRACES

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Figure 1: The first ten seconds of reverberation. The expanded portions show a superposition of 5 returns sampled over a period of 64 seconds. This shows the very high degree of stability both in amplitude and phase.

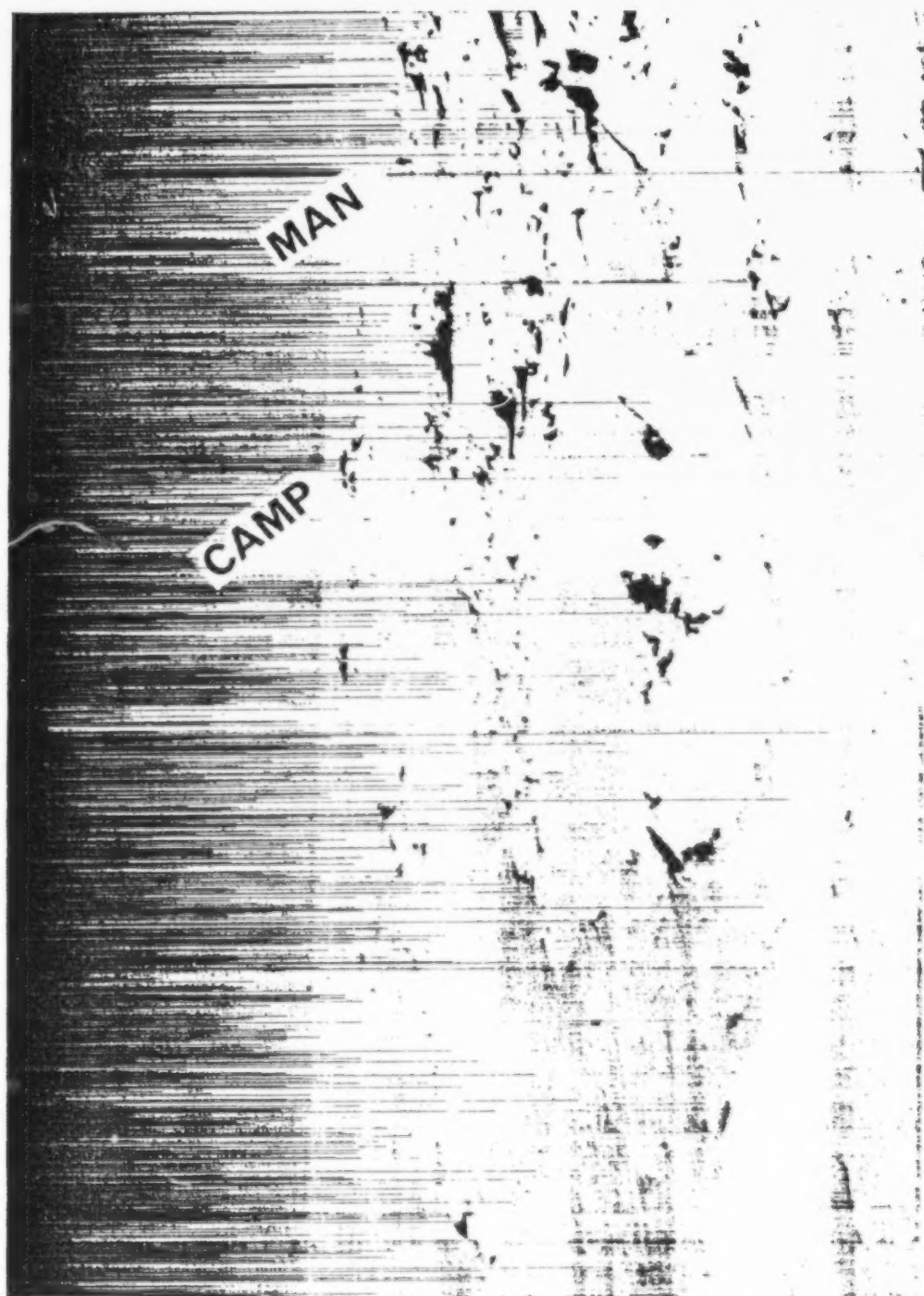


Figure 2: Ice cover near the camp

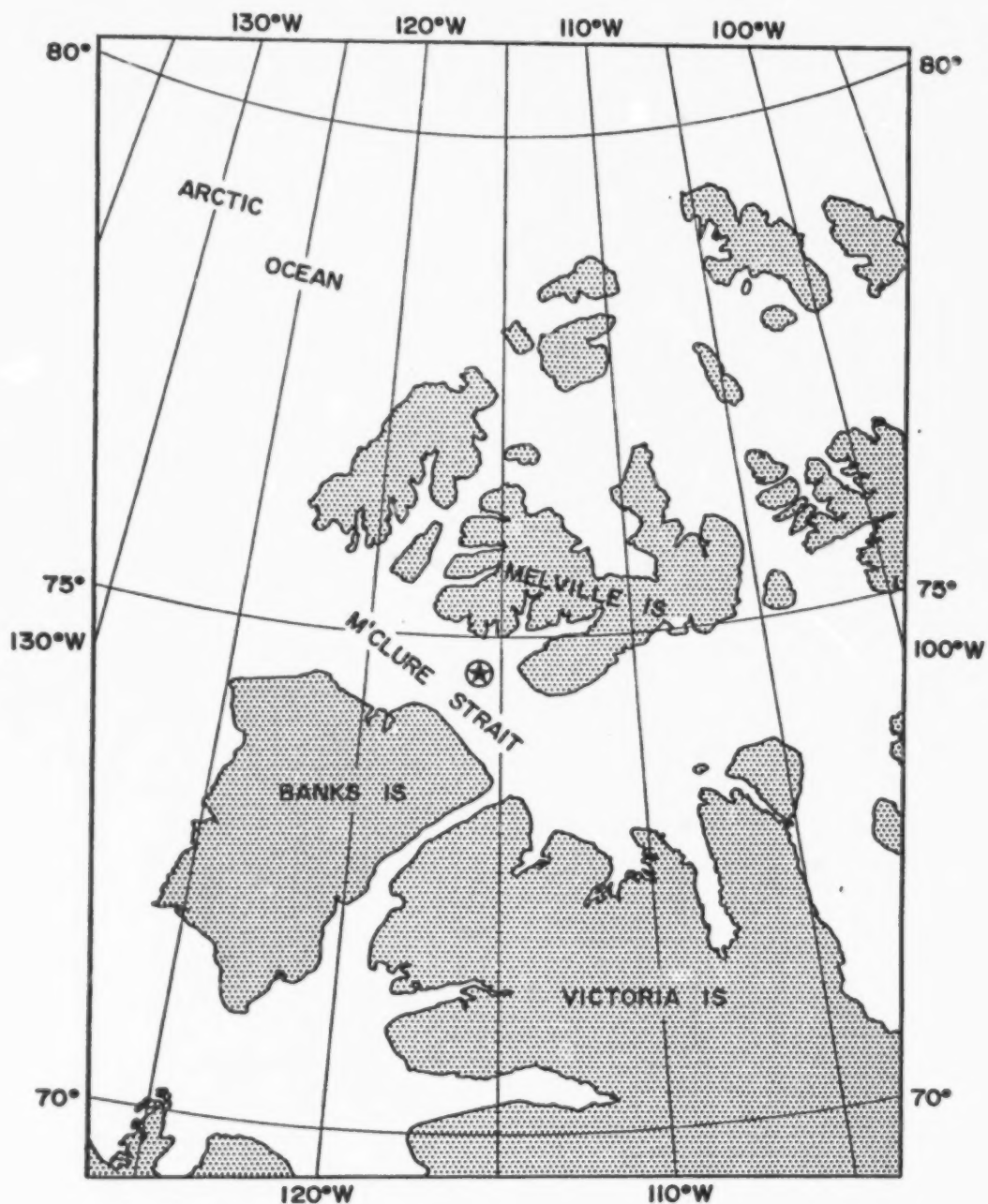


Figure 3: Location of the measurements

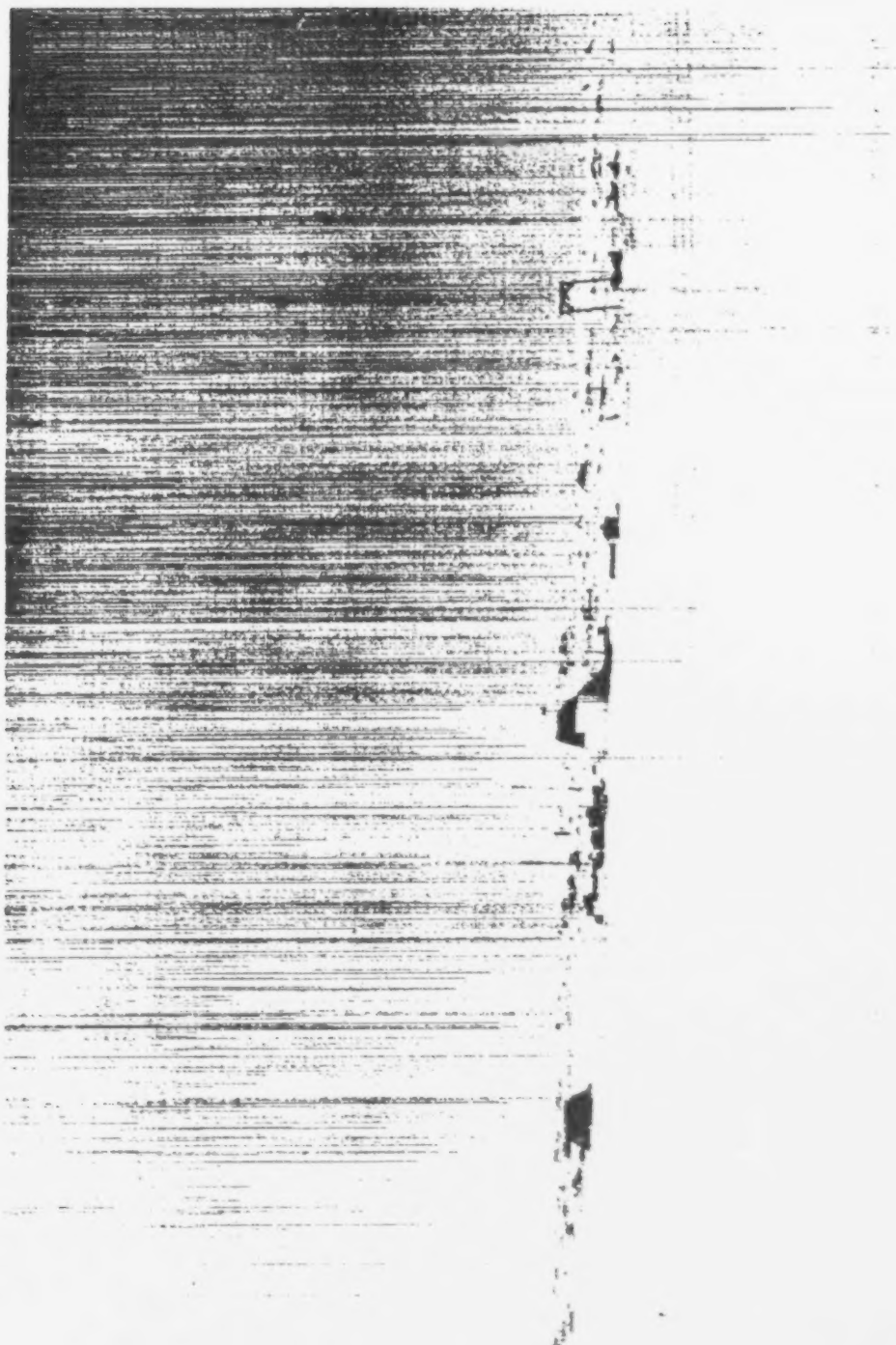


Figure 4: The Camp. Note the transition from smooth lead ice to the jumbled pack ice.

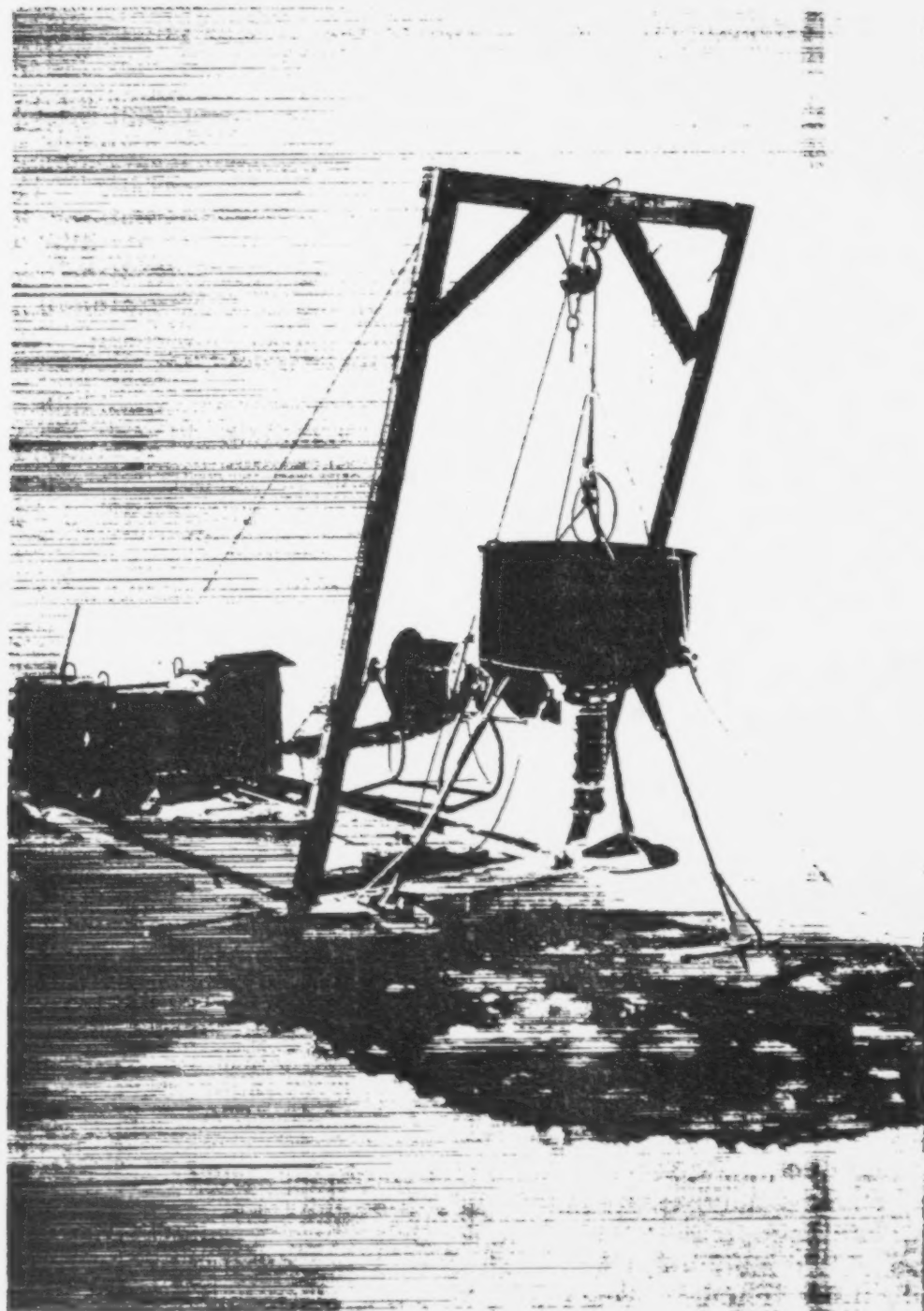


Figure 5: The transducer on its stand ready for lowering.

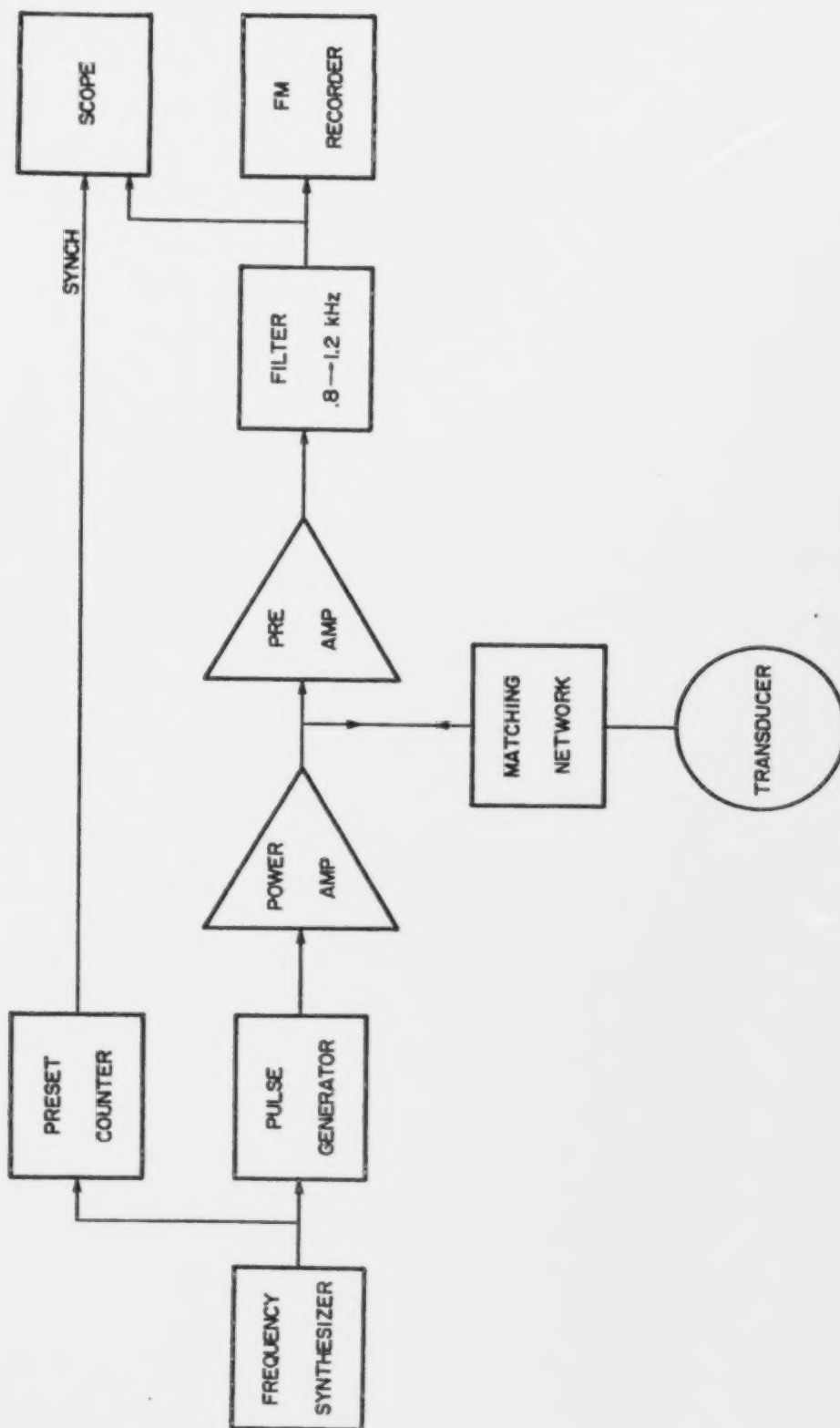
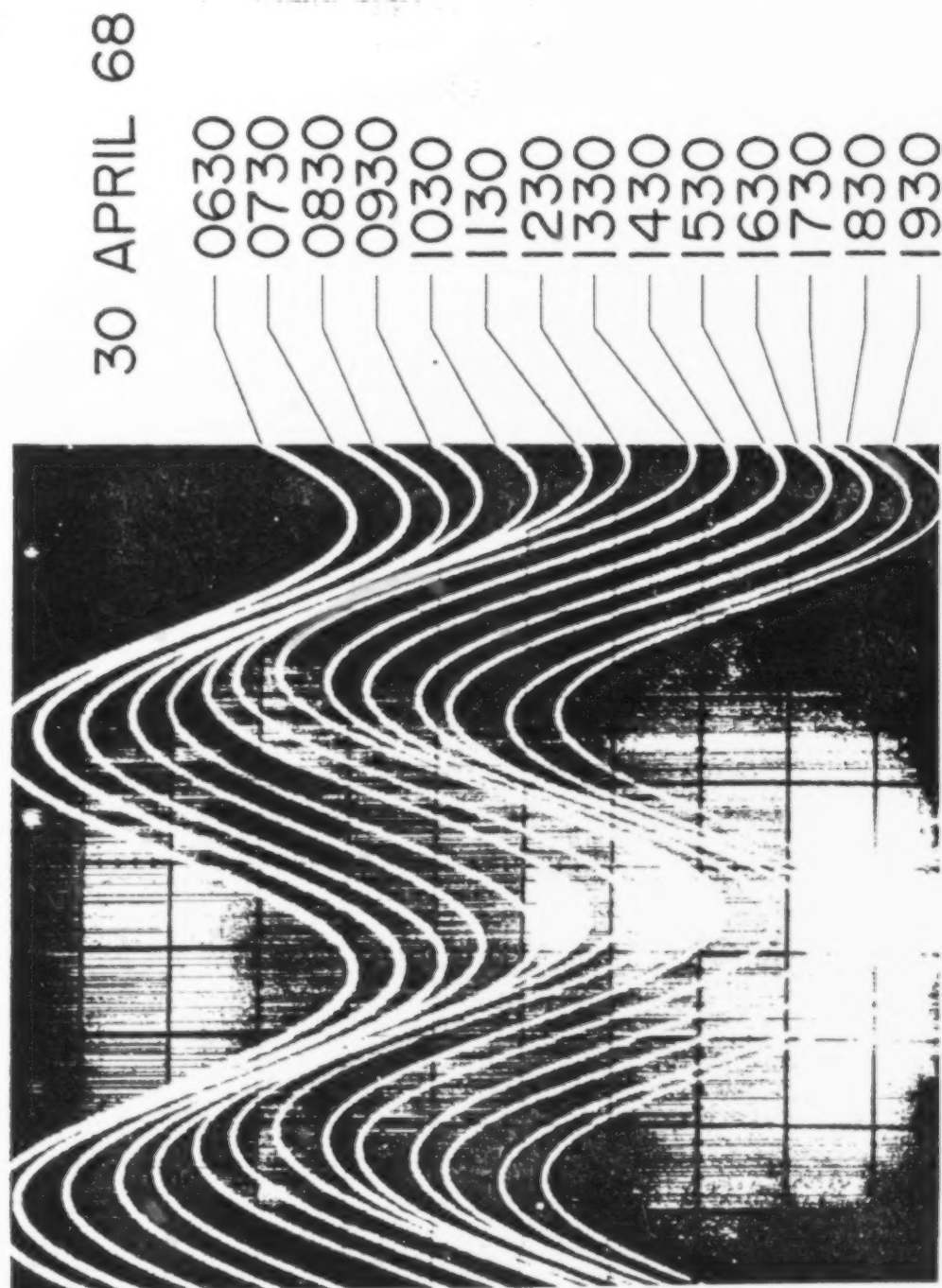


Figure 6: The Instrumentation



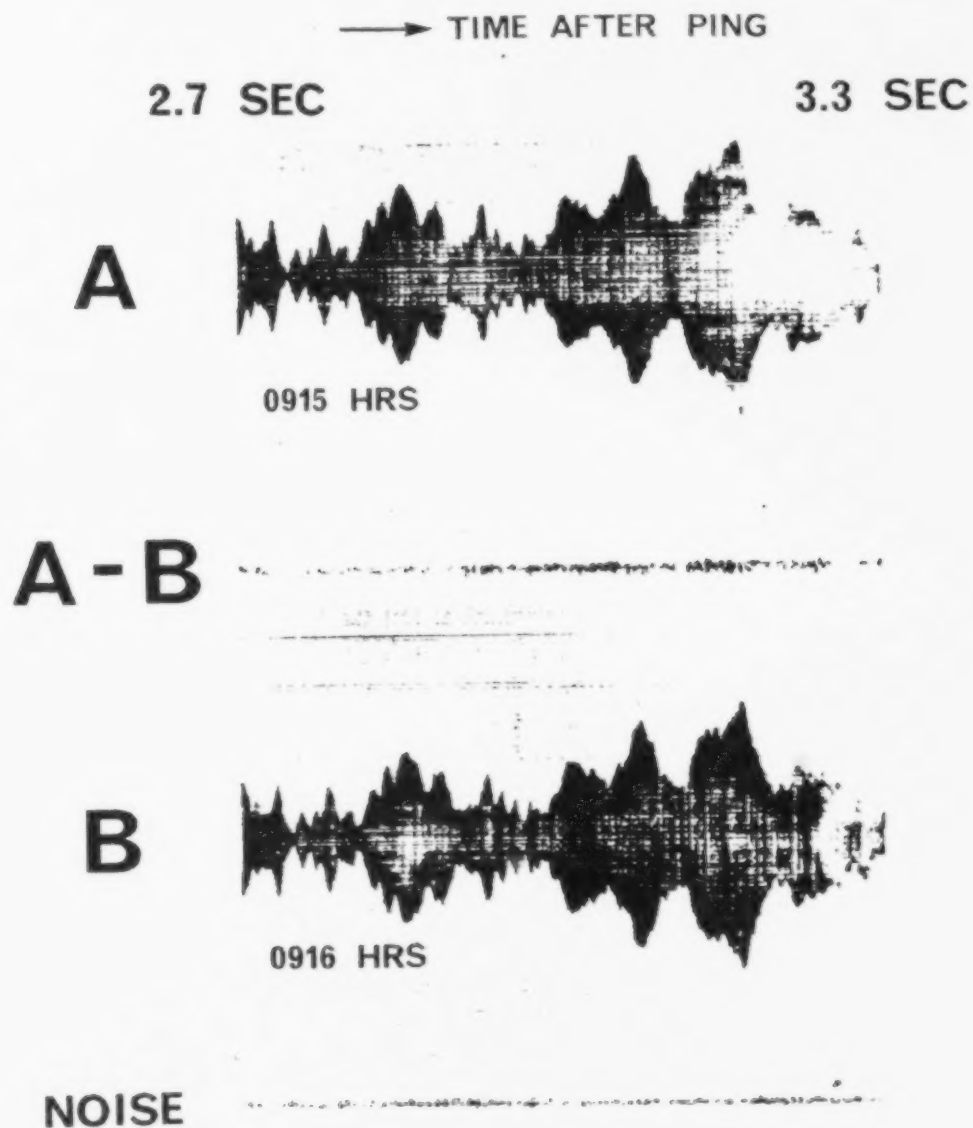
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Figure 7: The reverberation 5.7 seconds after the ping. Five returns were sampled over a period of 40 minutes. The variation in amplitude and phase are above the noise level.



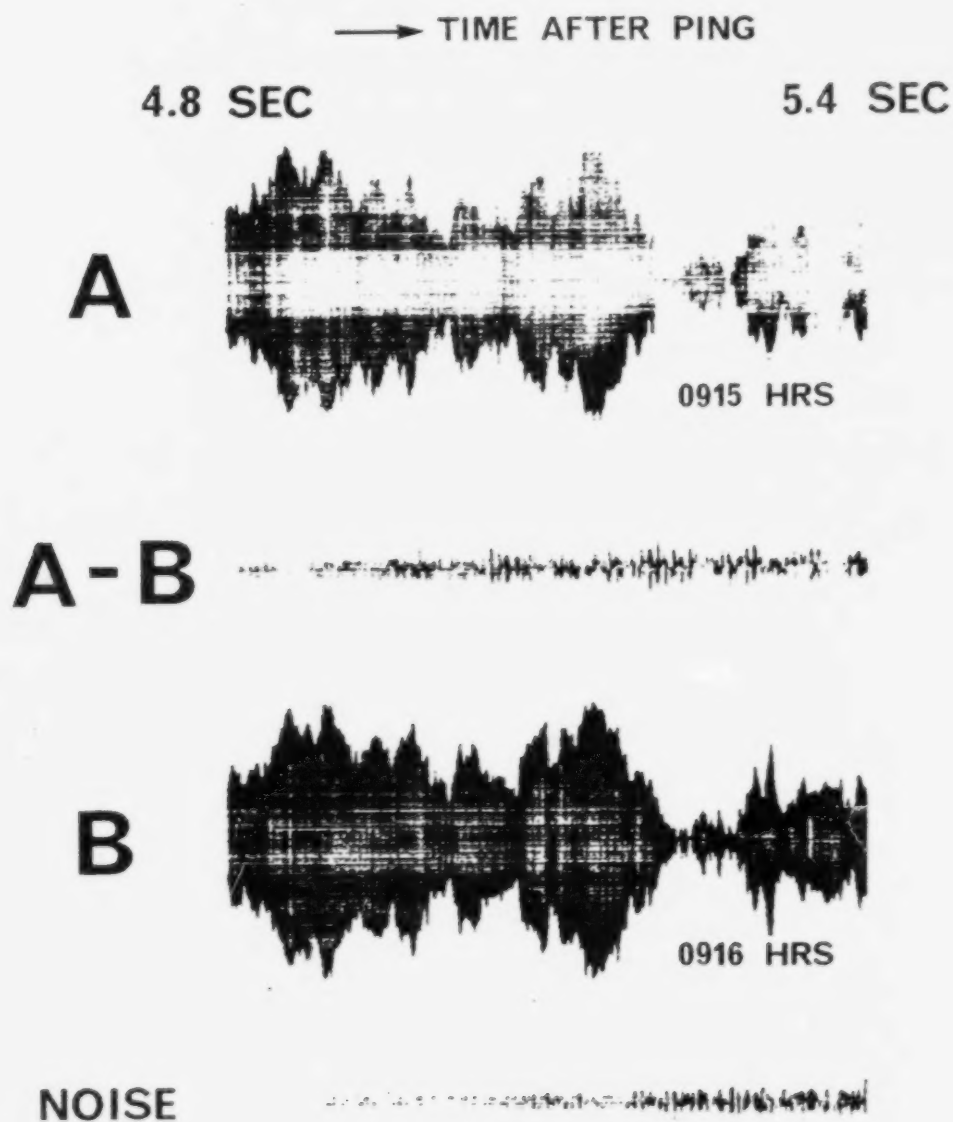
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Figure 8: Phase variations with time, of signals from the transducer received by a hydrophone two miles from the camp.



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Figure 9: Computer plots of portions of two reverberation returns A and B, and the difference between them A-B.



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Figure 10: Computer plots of portions of two reverberation returns A and B, and the difference between them A-B. Vertical gain is 12 db greater than in Figure 9.